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STUDIES FOR STUDENTS

BASELEVEL, GRADE AND PENEPLAIN.

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Thesis of this essay.—The attention given during the last fifty years to the processes and results of land sculpture has naturally resulted in the introduction of various new terms, three of which stand at the head of this article. It is desired to point out that too many meanings have been attached to the first term, "baselevel," and that some of them should be transferred to the other two, "grade" and "peneplain."

The original meaning of "baselevel."—Although the control exerted by sea level on river action has long been recognized, the importance of the control was more generally perceived by American students of geology when it was explicitly formulated in the term "baselevel" by Powell in 1875. The term soon became so popular, especially with American writers, that a

divergence of meaning has arisen with regard to it. It is therefore proposed to trace its history, with the hope of inducing geologists and geographers to use it in a somewhat restricted sense. It will be spelled here as a single word, disregarding the separation into two words by some authors and the hyphen of others, except in the first quotation.

Powell's original definition of "baselevel" is as follows, the parenthesis being in his text:

> We may consider the level of the sea to be a grand base level, below which the dry lands cannot be eroded; but we may also have, for local and temporary purposes, other base levels of erosion, which are the levels of the beds of the principal streams which carry away the products of erosion. (I take some liberty in using the term level in this connection, as the action of a running stream in wearing its channel ceases, for all practical purposes, before its bed has quite reached the level of the lower end of the stream. What I have called the base level would, in fact, be an imaginary surface, inclining slightly in all its parts toward the lower end of the principal stream draining the area through which the level is supposed to extend, or having the inclination of its parts varied in direction as determined by tributary streams.) Where such a stream crosses a series of rocks in its course, some of which are hard, and others soft, the harder beds form a series of temporary dams, above which the corrasion of the channel through the softer beds is checked, and thus we may have a series of base levels of erosion, below which the rocks on either side of the river, though exceedingly friable, cannot be degraded (1875, 203, 204).

"Baselevel" as thus defined seems to include three ideas. First, the grand or general baselevel for subaerial erosion is the level of the sea; second, a baselevel is an imaginary, sloping surface which generalizes the faint inclination of the trunk and branch rivers of a region when the erosion of their channels has practically ceased; third, local and temporary baselevels are those slow reaches in a river which are determined by ledges in its course further down stream.

There is some reason for thinking that Powell's intention may have been misunderstood with respect to the first and third of these ideas. The first, "the level of the sea," may have referred only to the actual area of the sea, and not to an imaginary extension of the sea level or geoid surface under the lands.

The third certainly referred to the faintly sloping reach of a river, and not to a level surface passing through the ledge of hard rock with respect to which the reach is worn down, although this latter meaning has become popular. The following citations will show that most writers seem to be agreed that baselevels may be local or temporary as well as general, but that there is no prevalent agreement as to the definition of either the general or the local baselevel.

Definitions of "baselevel" by various writers.—The following authors adopt the first of the above meanings. Gilbert writes:

> The land cannot be worn down below the level of the ocean. Geologists express this law by saying that the ocean is the "baselevel of erosion" (1896, 575).

Campbell says:

> If the streams are in their old age, the surface of the land will constitute a peneplain, and in their extreme old age, this peneplain will approach very closely to baselevel (665).

Tarr writes to the same effect:

> In no part of the valley can the stream cut below the sea level, or below *baselevel*, as it is called (265).

Russell quotes Powell, as if adopting his definition, but concludes that:

> The real baselevel toward which all streams are working is the surface level of the sea. . . . When a stream has lowered its channel nearly to baselevel, downward corrasion is retarded, but lateral corrasion continues. . . . The ultimate result of erosion is to reduce a land area to a plain at sea level (47–48).

Finally, Powell may be quoted again as follows:

> The baselevel of a plain is the level of the surface of the sea, lake or stream, into which the waters of the plain are discharged (1895, 34).

The second idea under the term "baselevel"—that of the imaginary undulating surface—does not appear to have been adopted by any of the many writers whose works I have looked over. It is perhaps on account of the elaborateness of this second meaning that it has not come more generally into use. Its partial adoption, however, is indicated by the following

extracts. It should be noted that nearly all the writers here cited imply that, after baselevel is reached by a stream, downward corrasion ceases.

McGee describes the streams of the coastal plain at about the head of Chesapeake Bay as "at baselevel" (1888, 617).

Darton says, when describing the dissection of the Piedmont plateau of Virginia:

> As the cutting reached baselevel a series of wide terraces were cut (584).

Winslow writes:

> The streams of the prairie country [in Missouri] have, in large part, reached baselevel, and are developing meander plains (310).

Fairbanks states that in southeastern California:

> Erosion has reached an advanced stage with the production of excellent examples of baselevelling. One of the best examples is the western portion of a granite ridge lying south of the El Paso range. It is bordered by long gentle slopes of gravel and bowlders, which extending upward into the shallow cañons reach almost to the summit. Viewed from a distance of ten miles but little of the mountains appears to project above the plane of deposition (70).

Salisbury's statement is as follows:

> The time necessary for the development of such a surface is known as a *cycle of erosion*, and the resulting surface is a *baselevel plain*, that is, a plain as near sea level as river erosion can bring it. At a stage preceding the baselevel stage the surface would be a *peneplain*. It is also important to notice that when streams have cut a land surface down to the level at which they cease to erode, that surface will still possess some slight slope, and that to the seaward. Along the coast, a baselevel is at sea level. A little back from the coast it is slightly higher, and at a greater distance still higher. No definite degree of slope can be fixed upon as marking a baselevel. The angle of slope which would practically stop erosion in a region of slight rainfall might be great enough to allow of erosion if the precipitation were greater. The Mississippi has a fall of less than a foot per mile. A small stream in a similar situation would have ceased to lower its channel before so low a gradient had been reached (1898, 73, 79).

J. Geikie writes:

> Running waters will continue to deepen their channels until the gradient by the process is gradually reduced to a minimum and vertical erosion ceases. The main river will be the first to attain this baselevel — a level not much above that of the sea (47).

Marr does not use the term "baselevel," but says instead:

A river which has established equilibrium is said to have reached its base-line of erosion, and no further work of erosion or deposit can occur until the conditions are changed (84).

Dryer states:

The lower Mississippi has reached its baselevel, or the lowest level to which its current and load will permit it to reduce its bed. In the lower reaches of a river the valley is soon cut down to baselevel, where the slope is gentle and the current too slow to carry the full load of sediment it receives. Deposition occurs and downward corrasion ceases (79, 154).

Powell makes the following statement in a discussion of reaches and rapids:

The slow reach is a baselevel, like that of a lake, below which the banks and hills on either side cannot be degraded (1894, 35).

Various other definitions, more or less aberrant from the original and discordant with each other, are found in the following citations:

Dutton took baselevel to be a condition:

The condition of baselevel is one in which the rivers of a region cannot corrade. As a general rule it arises from the rivers having cut down so low that their transporting power is fully occupied, even to repletion. The recurrence of upheaval terminates the condition of baselevel (224, 225).

According to Willis baselevel is a slope:

A baselevel is the lowest slope to which rivers can reduce a land area (1895, 189). The ideal lowest possible slope, which is called a baselevel, is perhaps rarely reached (1900, 27).

Hayes makes baselevel a mathematical plane:

The term baselevel, synonymous with baselevel of erosion, is [here] restricted to Powell's original use the general baselevel being sea level. There may be an indefinite number of *local* baselevels in any region, each being determined by the outlet of the stream whose drainage basin is considered; but only one *general* baselevel. It should be clearly understood, then, that a baselevel is not a topographic form, but a mathematical *plane*, which may or may not, and generally does not, coincide with a land surface (21).

When describing erosion by rivers, Scott writes:

A stage must sooner or later be reached when the vertical cutting of the stream must cease. This stage is called the baselevel of erosion or regimen

of the river, and it approximates a parabolic curve, rising toward the head of the stream (98).

Rice makes the following statement:

The condition of balance between erosion and deposition [by rivers] has been called by Powell the condition of baselevel (140).

Brigham writes as follows:

A baselevel is a plane to which denudation must reduce a stably poised land mass, and below which denudation cannot take place. The plane is that of the ocean surface The great river first cuts its bed close to the sea level, and we say that a portion of the valley is reduced to baselevel. It lacks a little of it, but the difference is so small that we neglect it. Gradually the valley widens, and the baseleveled strip extends up the stream toward the heart of the country (281).

Cowles gives a definition of "baselevel" which taken literally gives it the meaning of a process:

Denudation of the uplands and deposition in the lowlands results in an ultimate planation known as the baselevel (178).

The derivative use of baselevel as the name of a worn-down land surface does not seem to be so common now as it was some ten years ago. A few examples will here suffice.

Keith made frequent use of "baselevel plain," or simply "baselevel," as the name for a surface that had been reduced to faint relief, even though now uplifted and more or less dissected. He discusses the "considerable variation in the altitude of different parts of the baselevel" or old Tertiary land surface in the Catoctin region district of Virginia (373). He mentions "hill tops marking the dissected baselevel" of the Shenandoah valley (374). The term seems to be applied in at least one instance to a peneplain in saying:

It needs but little study of this baselevel to discover considerable inequalities in its surface (369).

Diller made equally free use of "baselevel plain" and of "baselevel" in his account of an ancient surface of erosion in northern California. He states that "the western edge of the baselevel, where it enters the mountains, has an altitude of 2,600 feet," and on a later page he suggests two ways in which the "deformation of the baselevel may be studied" (406, 430).

Kümmel writes of the "long erosion which resulted in the Cretaceous baselevel" of Connecticut (379).

Willis says:

> The tendency is in time to reduce the land to a gently sloping plain, which extends from the sea to the headwaters of the rivers. Such a plain is called a *baselevel*. A surface, which is almost, but not quite, a baselevel, is called a *peneplain* (1895, 188, 189).

Hill describes a persistent bench near Panama as:

> Representing an ancient baseleveled plain, which will be described as the Panama baselevel (197).

An essay by Van Hise describing a "baseleveled plain" is entitled "A Central Wisconsin Baselevel" (57).

I have had a small share in a similar use of "baselevel;" for example:

> The general upland surface of the Highlands [of New Jersey] is an old baselevel, in which valleys have been cut in consequence of a subsequent elevation (1889, 20: see also Davis and Wood, 384).

A review of the above citations, whose number might be greatly extended, shows that "baselevel" is given very different meanings by different writers. These meanings are: an imaginary level surface in extension of that of the ocean (the convex geoid surface); an imaginary mathematical plane; an imaginary surface sloping with the mature or old streams of its area; the lowest slope to which rivers can reduce a land surface; a level not much above that of the sea; a slow reach in a stream; a condition in which rivers cannot corrade or in which they are balanced between erosion and deposition; a certain stage in the history of rivers when vertical cutting ceases and their slope approximates a parabolic curve; an ultimate planation; and a plain of degradation.

Limitation of the meaning of "baselevel."—The diversity of the above definitions may be better perceived when it is noted that they are expressed in terms of very unlike quantities: imaginary surfaces, level, plane, or warped; a low slope; a part of a river; a condition of river development; a stage in river history; an ultimate planation; and an actual geographical form. It is evi-

dently desirable to associate "baselevel" with at most only a few of these meanings, preferably with only one; and to leave the others unnamed or to associate them with other terms. It seems to me advisable to limit "baselevel" to the first meaning, an imaginary level surface, and to define it simply as the level base with respect to which normal subaerial erosion proceeds; to employ the term "grade" for the balanced condition of a mature or old river; and to name the geographical surface that is developed near or very near to the close of a cycle, a "peneplain," or "plain of gradation." The following paragraphs may make the need of this discrimination clearer.

A full understanding of the development of land forms can be gained only by tracing the progressive changes of a generalized example from the initial stage through the various sequential stages to the ultimate stage of an ideal geographical cycle. This problem is encountered in an elementary form at the beginning of the study of land sculpture in physiography or geology, and at the very outset it is necessary to make definite and simple statement regarding the limit with respect to which the processes of normal subaerial erosion (weather and streams, without significant aid from wind or ice) may act. If the limit is defined in terms of the slopes that the streams of the region will have gained when they have reached a maturely balanced condition, the definition will be of no service to beginners; indeed, a limit thus defined is elusive and difficult of conception even by experts. The limiting surface is certainly of so great importance to the beginner that it must be briefly defined for him in terms of known factors, and the definition thus framed should remain serviceable through all later study. These conditions are satisfied when the beginner is told that the limit of subaerial erosion is the "level base" or "baselevel," drawn through a land mass in prolongation of the normal sea level surface. The fact that rivers erode their channels near their mouths below sea level and that special processes of erosion (winds and glaciers) may work below sea level, does not invalidate the general statement at the opening of the whole discussion; but these special condi-

tions must be explicitly considered later, especially those concerning glacial erosion. It suffices at first to recognize that in the ideal undisturbed cycle of normal erosion the baselevel must be more and more closely approached as time is extended.

This definition of "baselevel" as a level base certainly has the advantage of being easily conceived. Once conceived in the study of the ideal cycle, it needs no modification so long as the relative attitude of land and sea remains fixed. If the land rise or fall with respect to the sea, the baselevel takes a new position within the land mass, and further progress of erosion is then continued with respect to the new limit.

As the study of the cycle advances it becomes desirable to speak of various local or temporary controls of erosion: a rock ledge or a lake on a river course, the central basin of a dry interior basin either above or below sea level, the surface of a lake in such a basin. Nothing can be simpler than to imagine a level surface passing through any one of these controls, and rising or sinking as the control rises or sinks; and such a surface is naturally called a local or temporary baselevel. With the enlargement of conceptions that is required when the aggradation of depressions is considered at the same time with the degradation of elevations, Powell's more general term, "gradation," may replace "erosion;" the merit of this substitution will appear more fully in the following pages.

In view of the importance appropriately allowed to the idea of the level base with respect to which the erosion of valleys by rivers must proceed, it is curious that earlier writers did not give more explicit attention to it; but as far as I have read, they were so largely occupied with controverting the various older theories of the origin of valleys that it did not occur to them to give special name to limiting surface of erosion. Their understanding of the important principle here involved is to be read rather between the lines than in explicit statements. For example, Greenwood, in his curious book on *Rain and Rivers*, almost as remarkable for its admixture of jokes and polemics

as for its many admirable expositions of rain and river work,[1] contains the following account of the problems here considered:

Suppose a barrier of rock to run across any valley or river bed; when the bed of the valley or river on the upper side of the barrier has been worn down to a horizontal level with this barrier, it can *not* go lower. But as the barrier is cut through, the bed of the valley or river will be deepened *backward*, or from below upward, or towards the hills. The passage of the detritus and soil from the inclined upper parts of valleys is checked in the horizontal lower parts of valleys, and soil accumulates there. This is the origin of alluvial plains; and a river of any size, or any rapidity, may, at any distance from the sea, have *patches* of alluvial plain, where no lakes have ever been; that is, above every rapid or accidental barrier of hard ground. The only difference in the laws for the growth and gradient of these patches from those which regulate the growth and gradient of the plain at the level of the sea, is that they have no *increasing* cause for rising equivalent to the *forward* lengthening of the delta of the lower alluvial plain. These flat alluvial patches may be seen even in torrents, sometimes reaching from one cascade to the other. It is easy to perceive that these patches must be liable to constant change. They must be perpetually shortened by the recession of the lower barrier, and lengthened by the recession of the upper one. These principles are eternally at work on all valleys, from the smallest to the largest" (174–176).

The use of "horizontal" in describing the lower parts of valleys is curiously inexact in contrast to the keen recognition of the difference between what we should now call local and general baselevels, and of the aggradation of a flood-plain on account of the "forward lengthening of the delta."

The balanced condition of rivers.—Turning now more particularly to the problem of river action, we find that the balance between erosion and deposition, attained by mature rivers, introduces one of the most important problems that is encountered in the discussion of the geographical cycle. The development of this balanced condition is brought about by changes in the capacity of a river to do work, and in the quantity of work

[1] Here is a characteristic illustration of Greenwood's mixture of sense and nonsense: "The very soil on which we tread may be said to be on its road from the hill to the sea. No drop of rain *runs* an inch on the surface of the earth without, as far as it goes, setting some soil forward on its road to the sea, and it won't run back again. No return tickets are given. It will wait there, and go on by the nex-*t-rain*" (105).

that the river has to do. The changes continue until the two quantities, at first unequal, reach equality; and then the river may be said to be graded, or to have reached the condition of grade. This condition cannot be understood without rather careful thinking on the part of the expert as well as of the tyro. The idea of grade is not of almost axiomatic simplicity, like the idea of baselevel; its meaning must be gradually elaborated as it is approached. Moreover, a graded river does not maintain a constant slope; it changes its slope systematically with the progress of the cycle: but before taking up this element of the discussion a few paragraphs may be given to the consideration of "grade," as a common word used in a technical sense.

It should be noted in the first place that it is a condition of river development, not a surface, nor a stage, nor a form, for which the term "grade" is to serve as a name. The condition of grade must not be confused with the limiting under-surface of erosion, with respect to which the graded condition is developed; the name for this surface is "baselevel." Nor must it be confused with the stage in the history of river development in which the graded condition is reached; "maturity" is the name for that stage; but it may be noted in passing that the graded condition persists all through the old age as well as the maturity of an uninterrupted cycle. "Grade," meaning a condition or balance, must not be confused with the same word used in another meaning, namely, the slope or declivity of the river when the graded condition is reached; for "grade" meaning slope, varies in place and in time, while "grade," meaning balance, always implies an equality of two quantities. In fine, grade is a condition of essential balance between corrasion and deposition, usually reached by rivers in the mature stage of their development, when their slopes have been duly worn down or built up with respect to the baselevel of their basin.

There can be no question that the balanced condition of mature and old rivers deserves a name. It was to this condition that Powell called attention in his original discussion of land sculpture, and to which he devoted one of the meanings of

his term "baselevel." A name had already been suggested for the balanced condition by various writers, who called it the "régime" or "regimen" of rivers, while the slope of a river under this regimen was called its "*penté d'équilibre*" by Dausse and the "*Erosions-Terminante*" by Philippson (1886, 71.) But (1857, 759) "regimen" may be better used as meaning the rule of river action under which the balanced condition is developed and maintained; while "slope of equilibrium" may be taken as a descriptive phrase, too cumbersome for ordinary or frequent use, but essentially synonymous with "graded slope." "Baselevel" seems at best a very inappropriate name for a condition in which the idea of slope is essential; and when another and equally important use is made of this excellent word, its employment as the name for the balanced condition of rivers is all the more unsatisfactory. "Grade" is the most satisfactory term for the balanced condition or state of equilibrium of rivers on several grounds, in spite of certain objections that may be urged against it. Let us consider the objections first.

Origin and use of the term "grade."—One of my correspondents has objected to "grade" because, in the sense here adopted, the word means, etomologically, a step and not a slope. This objection seems to me of small value on account of the freedom with which new meanings are given to old roots. Language does not grow by rule but by use; and use has decreed that one meaning of the English word "grade" shall depart somewhat from the meaning of its Latin ancestor. The chapter on "Transference of Meaning" in a work on *Words and Their Ways in English Speech*, by two of my colleagues, Professors Greenough and Kittredge, may be consulted to advantage in this connection.

Another correspondent objects because the word "grade" is already in common use, meaning among other things, a slope, and the ratio of the vertical to the horizontal in a slope; but as a matter of fact no practical inconvenience has arisen on this account. The context suffices to indicate which one of the several meanings of the word is intended. Moreover, if we

should endeavor to escape the criticism of Scylla, by making up a new technical term in order to avoid the technical use of a common word in a new meaning, we should be met by the objections of Charybdis, who maintains that "every new technical term is a positive detriment to science." The objections to "grade" seems to me far outweighed by the many points in its favor, which may now be reviewed.

In favor of the term, it may be noted first that "grade," like "baselevel," is of a convenient form, ready for use as noun, adjective, and verb, after the handy fashion of the English language in many other cases. In the second place, the sense of the verb "grade," as employed by engineers (to prepare, by cutting and filling, a smooth bed of gentle slope for a railroad or other line of transportation), is closely analogous to the meaning here advocated for the verb "grade" as used by geologists and geographers: a river grades its course by a process of cutting and filling, until an equable slope is developed along which the transportation of its load is most effectively accomplished. In the third place, "grade" lends itself admirably to the formation of such terms as "degrade," "aggrade," and "gradation;" "degrade," in the sense of to wear down, has been in use for some time by geologists; "aggrade" is an excellent addition to our terminology, proposed by Salisbury (1893, 103) in the sense of building up; while "gradation" is Powell's term for the general process of wearing down elevations and filling up depressions, in the production of lowland plains (1895, 30). Finally, the word has already made a beginning towards acquiring a useful place in scientific writings.

The use of "grade," in the sense here advocated, was almost reached by Gilbert in his description of hills of planation, covered with stream gravels: "The slope of the hill depends on the grade of the ancient stream, and is independent of the hardness and dip of the strata" (1877, 130); and again in his account of how a river "tends to establish a single, uniform grade," and "an equilibrium of action" (1876, 100). It was in consequence of a suggestion from this philosophical writer that I introduced

"grade" as a substitute for various paraphrases in my own work in 1893 (1894, 77).

McGee considers the control of the balanced condition of rivers under the "law of river gradation" (1891, 265).

Mill uses "grade" as a verb, essentially in the sense here advocated: "Ultimately the river grades its course and flows uniformly along a uniform slope" (56).

Gannett has adopted "grade" as a technical term in Folios 1 and 2 of the *Topographic Atlas of the United States*. In the first he writes:

> There finally comes a time when the river ceases to erode, or rather, it deposits as much as it erodes. A river is then said to be graded.

In the second, a special sheet with explanatory text is devoted to "A Graded River," the example chosen being the lower Missouri:

> At this stage the lower portion of its [a river's] course has been eroded to almost as low a stage as possible, and its slope has become very slight, so that its cutting power is trifling. This part of the stream is said to be "graded."

Johnson uses "gradation" as involving both degradation and aggradation, and as producing a "graded slope," a slope of "equilibrium easily disturbed, yet constantly maintained" (620).

"Grade" may therefore be regarded as having already gained recognition in the sense here advocated, as a replacement of one of the meanings of "baselevel."

There remain to be considered several reasons in favor of giving different names to the limiting base of sub-aerial erosion, and to the balanced condition in which rivers spend most of their lives while approaching the limit of their work. The first reason is based on the persistence of the base level surface all through the cycle, without change from its initially complete extension, in contrast to the gradual introduction and slow extension of the condition of grade during the mature and older stages of the cycle. The second is based on the fixity of the baselevel surface in contrast to the variation in the slope of graded rivers. The third springs from the essential simplicity

in the meaning of "baselevel," in contrast to the complexity and variety of conditions ultimately gathered under the term "grade."

Baselevel is complete from the beginning, and permanent to the end; Grade is slowly introduced and gradually extended.—The conception of the general baselevel must be made at the outset as that of a completed surface extending beneath the land mass under consideration at the beginning of the cycle, and so remaining as long as the advance of the cycle continues undisturbed. In the ideal case, which provides the general scheme with respect to which all other cases are classified, the land mass once uplifted is supposed to stand still until it is worn down flat. This supposition is so artificial, and does so great violence to much that is known as to the behavior of the earth's crust, that some students are therefore disposed to discard the scheme of the cycle altogether in the study of the sculpture of land masses, overlooking the fact that however many movements of a land mass may be discovered, the many incomplete cycles that are separated by these movements must each be treated essentially according to the scheme of the ideal cycle. In every case, the processes of land sculpture, quickened or slackened in consequence of the new attitude given to the region, go on with respect to the new attitude of the baselevel within the land mass.

Even during the movement of the land mass, it must be conceived of as rising or sinking through a fixed and complete baselevel surface, with respect to which its carving is even then begun, and long afterwards continued, during the ensuing time of relative or absolute rest. Hence, for every cycle or partial cycle of erosion, the imaginary baselevel surface is immediately conceived as complete at the outset, and as thenceforwards remaining unchanged. Local baselevels are also complete, in extending at once as far as the imagination wishes to carry them; they rise or fall slowly with their control.

It is far otherwise with the development of the graded condition. The previous paragraphs have explained that the devel-

opment of grade depends on the spontaneous adjustment of the capacity of a river to do work, and the quantity of work to be done by the river. It is well understood that this adjustment is realized by the larger streams relatively early in the cycle; by those of medium and smaller size at later and later stages; and hence that the condition of grade is deliberately introduced and systematically extended through all parts of a river system as the cycle advances. The condition of grade needs no mention when the scheme of the cycle is first presented. Truly, it might be considered as an accompaniment of the youth of a cycle in those special cases where a large river is running across a slowly rising region of weak rocks, for here the condition of grade may be continuously maintained during the period of uplift. But it is not in connection with special cases of this kind that a first acquaintance with the condition of grade is best made. Its fuller meaning is not likely to be well understood unless presented with something of the deliberation that characterizes the actual development of graded rivers. Indeed the conception of grade is likely to be an embarrassment if presented too early.

The extension of the graded condition over all parts of a river system introduces a thoroughness of organization in the processes of land sculpture that warrants the use of the term "maturity," as the name of the stage of the cycle in which the organization of river systems is chiefly accomplished. The growth of organization goes with the development of grade. In every reach of a river in which the graded condition has been attained, the lowest point on the reach is always coincident with and dependent on a controlling baselevel (as above defined) either general or local, and river action at any point in the graded reach is then delicately correlated with that at every other point. River action in such a reach may justly be said to be organized, inasmuch as a change in form or action at any one point involves a change at every other point. Adjacent reaches, separated by a fall on an ungraded ledge or by an unfilled lake, are independently organized; a change

in one does not necessarily call for a change in the other. But when all falls and rapids are worn down, and all lakes are filled up, and the entire river system is graded, as is characteristically the case in the late-mature stage of a cycle, the organization of the system is so complete that all its parts are correlated. A change at any one point then involves a change, of infinitesimal amount perhaps, all through the system. It is this condition of organization that Gilbert alluded to in describing the "interdependence" that comes to be developed among the different lines of a river system, as a result of which "a disturbance upon any line is communicated through it to the main line and thence to every tributary"—(1877, 124).

The actual slopes of the different parts of a graded river system vary from a faintest declivity in the lower course of the trunk river to decidedly steeper declivities in the uppermost courses of the headwater streams. If any stream line is followed from head to mouth its profile will show a curve, approximating theoretically to the flatter part of one wing of a parabola;[1] but when studied in detail, the normally continuous decrease of slope down stream is found to be seldom realized. The entrance of a tributary is usually accompanied by a decrease of slope up-stream and an increase of slope down-stream from the tributary mouth; the spasmodic action of floods introduces some faint symptoms of disorder in otherwise simple slopes; and in this connection the inequalities due to what McGee has called "varigradation" are to be considered (1891, 269; see also Oldham, 1888). All these complications in the slopes of a graded river system make it extremely difficult to conceive of a surface which shall generalize the river slopes. Indeed, it is hardly worth while to attempt this conception, for the reason that all the value of the imaginary surface is to be found in the actual slope lines of the graded river systems by which the surface is guided. It is with respect to the sloping course of a graded stream that the valley

[1] It is evidently only under the assumption that the baselevel is not a convex level surface, but a plane that the profile of a river can be described as a parabola. The actual profile of a large river, such as the Mississippi, is convex to the sky.

sides are to be worn down; it is with respect to the graded lines of a river system that its whole basin is to be worn down. This conception, as announced by Powell, is of fundamental importance; but it does not seem to gain in clearness or strength by expressing the control of erosion in terms of a warped surface, guided by the branching lines of the graded river system, instead of expressing it distinctly in terms of the branching stream lines themselves. Reference will be made again to this aspect of the problem further on.

Not only do graded streams vary in slope in different parts of a river system; the slopes may vary greatly in two neighboring river systems at the time of the general establishment of their grade. This may be illustrated by considering the unlike conditions obtaining in two rivers, alike in volume, but one flowing through an upland of resistant rocks, the other through a similar upland of weak rocks. The first would have to cut down a deep valley to a gentle slope before grade was reached; because its load would be slowly delivered from the resistant rocks of its valley walls, and high walls would have to be produced by deep valley cutting before a balance could be struck between the increasing load from the walls and headwaters and the decreasing capacity of the river. The second river could not cut so deep a valley, however weak the rocks of its bed, because it would have an abundant load supplied by the rapid wasting of its valley sides, even when they were of moderate height, and a strong slope down the valley would be required in order to maintain a velocity with which the graded stream could bear the abundant load away. Only as the whole upland is worn down in the later stages of the cycle could the second stream wear down its valley to a gentle slope; and then the valley would be still shallower than when grade was first attained.

The principle here considered is clearly recognized by Gilbert, who instances the Platte as a river of the second kind, and states that Powell also had so described it (1876, 100). The difference between the two kinds of rivers is not satisfactorily indicated in terms of baselevel; but it is clearly presented by

stating that one has developed its grade on a faint slope, the other on a stronger slope.

The incapacity of the Platte to deepen its valley leads Gannett to describe it as an "overloaded river(1900); but this phrase is not altogether satisfactory, because it overlooks the fact that rivers refuse to be overloaded. A river will most dutifully work up to its full capacity; it is ready to increase its capacity by increasing its slope through aggrading when necessary (as stated below), and thus it may become heavily loaded; but like the traditional llama it refuses to carry an overload. Like all streams with braided channels, the Platte is well graded, as well graded as the typical lower Missouri, although the quantity and texture of its load require it to maintain a relatively strong slope.

Baselevel remains fixed all through an uninterrupted cycle : the slope of graded streams must vary as the cycle advances.— After a river system has attained a maturely graded condition, it will maintain a graded condition through all the rest of the undisturbed cycle; but it is important to recognize that the maintenance of grade, during the very slow changes in volume and load that accompany the advance of the cycle, involves an appropriate change of slope as well. Instead, therefore, of having to do with a fixed control of erosion, such as is found in the general baselevel of a region, we have here to do with a slowly, delicately and elaborately changing equilibrium of river action, accompanied by a corresponding change in river slope. For example, a large river in a mountain valley may reach grade in the early maturity of its region. It will then flow with a rushing current on a rapidly sloping bed of cobblestones; and it may stand hundreds or even thousands of feet above baselevel. In the old age of the region, the same river will flow with a sluggish current on a nearly level bed of sand and silt through a peneplain, only a few tens or scores of feet above baselevel.

This is a point that is not generally enough recognized. It is too often implied — in the absence of explicit statement to the contrary — that when a river is once balanced between

erosion and deposition its slope thenceforward remains constant. The beginner would gather this understanding of the question from several of the definitions of "baselevel" above quoted, but such is evidently not the case. When a stream is first graded, its channel is not level, and it has not reached the base of its erosive work. In virtue of the continual, though slow, variations of stream volume and load through the normal cycle, the balanced condition of any stream can be maintained only by an equally continuous, though small, change of river slope, whereby capacity to do work and work to be done shall always be kept equal. It might at first be thought that changes of this kind would be perceptible, and that there would be occasional departures of a river from the graded condition; but such is not the case, because the change in the value of any variable in a unit of time is only by a quantity of the second order, by a differential of its total value. Once graded, a river will never depart perceptibly from the graded condition as long as the normal advance of the cycle is undisturbed. The slope of a river must necessarily be steeper on the first attainment of grade in early maturity, when an abundant load is received from the steep valley sides and the active headwater, than in late old age, when the valley sides have been worn down almost level, and when the even headwater streams are weak and sluggish. Hence, just as a graded river has slopes of varying declivities in its different parts at any one time, so the slope at any one part of the river must vary at different times in the successive stages of the cycle.

Not only so: it is eminently possible that the slope of a graded stream may have to be increased for a time after it has been first attained, for there is no necessity that the load should cease increasing just when its value has risen to equality with that which the stream can transport. There is much probability that, after grade is reached in a normal, undisturbed cycle, a river may have for a time to aggrade its valley floor until the time of maximum load is reached: and only after the maximum gives way to a decrease of load can there be a beginning

of that very slow and long-continued decrease of river slope which continues through late maturity and old age. Furthermore, if at any time in the cycle a change of climate should occur, new slopes would have to be developed by the streams in order to bring about a new balance between erosion and transportation under the new relation of load and volume. If, for example, the changes were from humid to arid conditions, all the valley floors would have to be steepened by aggradation. If from arid to humid, the graded valley floors would be sharply trenched, and in time reduced to lower slopes. There can be little doubt that under an increased rainfall the "baselevel" described in south-eastern California by Fairbanks would be sharply dissected, quite independent of any elevation of the region. I have already discussed certain aspects of this problem (1896, 377).

The clearest account that I have found of the normal variation of the graded slope is in the paper by Johnson already cited. He says that the graded slope "continually alters its inclination. There is a slow departure from equilibrium, and there is closely following readjustment toward recovery of it." The graded slope passes through its "transformations with a slowness comparable to that of mountain wear. It keeps pace with the slow growth of the débris mass following upon mountain lowering." But, if a stream be deprived of the greater part of its load by some abnormal changes, it "would at once attack its former slope of equilibrium, and rapidly, though at a progressively slowing rate, lower it. On the other hand, its load largely increased, the stream would rapidly build up the slope. In either case, however, it would come to a stand at a new grade of equilibrium" (1901, 621).

The same author attaches much importance to the effect of climatic changes on graded river slopes. When describing the dissection of the High plains, he says:

> It is not necessary, in order to account for change in behavior of the traversing streams, to appeal to deformation. A sufficient cause may be looked for in change of climate. There is record of erosion, with reversal to deposition and rebuilding, and reversal again finally to erosion, and there is reason

for believing that this series of interruptions of the gradation cycle was an effect of climatic oscillation rather than of earth movement (1901, 628).

This is by far the most striking actual example of varying graded slopes on record: an example that is easily defined in terms of changing grade, but not in terms of changing baselevel. It is much more satisfactory to describe the High plains in terms of stronger or fainter graded slopes than to consider them "near baselevel," as has been done in spite of their standing at altitudes of 4,000 feet and more.

The conception of grade must therefore include the conception of different and changing slopes in large and small streams, in mature and old streams, in streams dissecting weak and strong rocks, in streams of arid and humid regions. The conception is of the greatest value as a supplement to the simpler idea of baselevel; but it is so intricate that it cannot be fully apprehended until the whole course of the cycle is patiently worked through. Yet a still further extension of the conception remains to be considered.

Baselevels are of only two kinds, general (permanent) and local (temporary); Grade includes not only the balanced condition of large and small, mature and old water-streams, but that of all kinds of waste streams as well.—A final reason for giving different names to the limiting base of subaerial erosion and to the balanced condition of the mature and old streams that are working with respect to the limiting base is found in the essential identity of conditions in graded water streams and in graded waste streams, and in the strong unlikeness between the attitude of a baselevel surface as defined in any of the above citations and the slopes often assumed by graded waste streams. These are points to which the geologists and geographers of the older schools gave little or no attention: indeed it is only about fifty years since some of the leaders of our science taught that rounded hills could not be formed by subaerial erosion and that they must be the work of the sea. It is now well understood, however, that slopes covered with soil of local or up-hill derivation are really "drained" by an association of many graded waste

streams, whose behavior closely resembles that of graded water streams.

The first development of the balanced or graded condition in waste streams usually takes place on the outcrops of the weaker rocks that are exposed on freshly cut valley sides. Here graded waste slopes are locally developed; the adjoining waste streams form a sheet or cloak of waste which creeps slowly down the slope, while untamed ledges of harder rocks are still kept bare by the removal of waste from their surface as fast as it is formed. These represent the falls and rapids of water streams, because the waste from above the ledges passes over them quickly; while the graded waste-covered slopes represent the graded reaches of water streams, where the movement is more regular and leisurely. The less resistant of the bare ledges are the first to retreat under cover, permitting the grades below and above to unite in a single continuous slope; and so on, until all ledges are concealed under a graded sheet of waste, and the sharp, vigorous forms of youth and early maturity merge into the subdued and tamed forms of passing maturity and approaching old age.[1] During the progress of this change, there may be abundant examples of captures of one group of waste streams by the leading members of another group, especially in regions of tilted strata; thus increasing the resemblance of waste streams and water streams, until one is tempted to regard the difference between them as one of degree rather than of kind.

As maturity passes into old age all the elevations are worn lower and lower and the graded cloak of waste covers more and more of the surface. As the later stages of the cycle are approached, the whole region, monadnocks excepted, is reduced to moderate relief and bare ledges are rarely seen. On the faintly sloping forms of advanced old age the graded sheet of waste covers the entire surface between the water streams. Everywhere gently waste-covered slopes lead from the low

[1] I have pursued the comparison of water streams and waste streams somewhat further in my paper on "An Excursion to the Grand Canyon of the Colorado (1901, 176).

arched divides to the streams. The surface soil, greatly refined in texture by long exposure to the weather in its deliberate journey slowly creeps and washes to the streams, and the relief is reduced to smaller and smaller measures. The condition of grade, at first developed in the lower course of the larger rivers, next in their branches and headwaters, then on the valley sides and over the hills, has thus been extended all over the region. The organization that at maturity characterized the water streams has come in old age to characterize the streams and sheets of waste all over the land surface. From the beginning to the end of this process, there is steady progress without break or interruption through the normal cycle. There is an essential unity of development through the whole of it. It is very desirable that this unity should be expressed in the terms employed in the description of land sculpture and land form; and that the balanced condition of water streams and waste streams alike should be expressed by such a term as grade, rather than that an artificial distinction between them should be introduced by speaking of the balanced rivers as defining a "baselevel," while balanced waste streams are given some other name by which their close affinity to graded water stream is concealed.

An old land surface, sheeted over with a graded soil cover, is a peneplain of erosion or of gradation; it passes slowly into a plain of gradation. It is almost the realization of that imaginary baselevel surface described by Powell as "inclining slightly in all its parts toward the lower end of the principal streams draining the area through which the level is supposed to extend, or having the inclination of its parts varied in direction as determined by tributary streams;" but this imaginary surface is elusive and intangible, because of the impossibility of defining the stage of stream development when it should be introduced, and the length of graded stream course that it should follow; while on the other hand the graded land surface is a reality whose gradual development and slow change is one of its essential characteristics.

Until the imaginary surface is thus realized, it is hardly worth while to attempt to conceive it; for as far as the control of erosive processes is concerned, that is better exercised (as has been stated already) by the visible skeleton of the surface that is seen in graded streams than by the surface itself. It is always with reference to the graded course of the main river that the side streams are graded; it is with reference to all the graded streams that the slopes of the interfluves are graded. These relations of branch to trunk and of side slopes to streams are of the very greatest importance and must be considered with the utmost care; but the imaginary surface passing from river to river under the hills of the interfluves has relatively little importance as a control of the processes of erosion. With every extension headwards along the graded channels of branching streams, the surface becomes more warped and wrinkled, more difficult to conceive, more likely to differ as conceived by different minds. It must be not only irregularly warped when first defined, but it must vary slowly in form and slope. Just as no limit can be set to the headward part of the graded main stream or to the number of graded branch streams to be taken as guides for the imaginary warped "baselevel," so no limit can be set between the graded stream courses and the graded waste slopes of their head or along their sides. The imaginary surface should, if conceived at all, follow the lead of *all* the graded lines and surfaces as fast as they are developed; it should be extended as they are extended, modified as they are modified. But if this be agreed to, part of the imaginary surface becomes a real surface, and the rest may be neglected until it also is realized.

Just as every reach in a stream is graded with respect to the next down-stream barrier or local baselevel, so every waste slope is graded with respect to the ledge or cliff at its lower margin; the lowest reach, ending at the river mouth, is graded with reference to the general baselevel or the ocean; the lowest graded slope of a valley side is graded with reference to the stream (or flood plain) in the valley bottom. Again, every bare ledge on a mountain side will, in time, be graded (or consumed) by the

headward growth of the graded slope next below it, just as every ledge of rocks that makes a fall or rapid at the head of a reach will, in time, be obliterated by the up-stream extension of the graded reach. (In both cases, when the time of extinction of the ledge is attained, the waste slope and the stream reach will probably have been worn somewhat farther into the land-mass, assuming a somewhat fainter declivity—that is, coming closer to baselevel—than was the case while the ledge still existed.)

The close similarity, the real homology between the two classes of streams, makes it all the clearer that "baselevel" is not a good term to apply to either. It is not desirable to say that a hillside ledge is "baseleveled" when it is worn back so far that it disappears under the slope of the growing sheet of waste; yet it is certainly desirable to indicate by the use of an appropriate terminology that the disappearance of the ledge has been accomplished by changes of the same kind as those which have caused the obliteration of falls and rapids in rivers. Hence it seems desirable to say that every ledge, in valley side or stream bed, will in time be graded—not baseleveled—with respect to the attitude assumed at that future time by the graded—not baseleveled—reach or slope next below it.

It is, perhaps, on account of the elusive character of the imaginary warped surface that its definition is sometimes couched in indefinite language. In the original definition, Powell said:

> I take some liberty in using the term level in this connection, as the action of a stream in wearing its channel ceases, for all practical purposes, before its bed has quite reached the level of the lower end of the stream. What I have called the baselevel would, in fact, be an imaginary surface, inclining slightly (1875, 204).

In a later paper he said again:

> It will be understood that the land plain which is brought down to the level of the sea has its margin on the seashore, and that it extends back from the shore a distance which may be miles or hundreds of miles. As it stretches back, its surface rises slightly. The whole plain is not

brought down absolutely to the level of the sea, but only nearly to that level (1895, 34, 35).

Salisbury states that "no definite degree of slope can be fixed upon as marking a baselevel." Geikie defines baselevel as "a level not much above that of the sea." Brigham writes:

> The great river first cuts its bed close to the sea level, and we say that a portion of the valley is reduced to baselevel. It lacks a little of it, but the difference is so small that we neglect it.

These qualified statements are apparently the result of attempting to define a surface in terms of its variable feature, slope, instead of in terms of its constant feature, balance of activities. Whatever slope is agreed upon must change to a fainter slope if more time is allowed; but the balance, once struck, is always maintained as long as the cycle endures. Another cause of difficulty in definition seems to have arisen from giving the same name to a variable and to its limit. Both the imaginary warped surface and the actual peneplain are essentially variables; their variations are similar and systematic; they both approach, but never reach the limiting base of subaerial erosion. The latter is essentially a constant, accurately definable from the beginning, and remaining unchanged while the variable surfaces approach it. It may be defined as the limit of either of these variables in a strictly mathematical fashion. The baselevel is the level base toward which the land surface constantly approaches in accordance with the laws of degradation, but which it can never reach.

Plains and peneplains.— The names for surfaces of ultimate and penultimate subaerial erosion deserve brief consideration. My own preference, prejudiced, perhaps, by a share that I have had in making up names, would be to avoid "baselevel" as a technical name for any geographical form, to use "plain" sparingly for surfaces of erosion, because of the rare occurrence of complete or ultimate planation; and usually to employ "peneplain" as the name for the penultimate form developed in a cycle of erosion. It was in order to avoid the implication of complete erosion, and the objections

that such an implication aroused, that the term peneplain was suggested thirteen years ago. This word gradually came into use with quotation marks and an explanatory footnote. The footnote disappeared first, and now the quotation marks are frequently omitted as if the word had gained an established position, although among writers in Great Britain the need of the term is still so little felt that it is generally mentioned as an American invention when used at all, instead of being fully adopted, like delta and atoll, without explanation or acknowledgment.

There seems to be today less hesitation regarding the acceptance of the idea of far-advanced subaerial degradation than there was fifteen years ago — witness the use of "plain of erosion" by Hobbs (137) as a name for the worn-down surface, now uplifted and dissected in the uplands of Connecticut; nevertheless it still seems desirable to speak of such surfaces as peneplains in the absence of proof that they were actually reduced to plains. The alternatives for peneplain are as follows:

Powell contrasts "gradation or true plains" with "diastrophic plains" (plateaus), the former being produced by gradation, a "process accomplished through the agency of water," and the latter by the uplifting of the earth's crust. This use of "gradation" is a natural complement of the use of "grade" in the sense advocated in this essay. Gradation plains are then treated under four heads: sea plains, lake plains, stream plains, and flood plains. Of the first class it is said:

> Whenever in any region the process of slow upheaval comes to an end, and such district is still subject to degradation by rains and streams, the process of reduction goes on until the surface is brought down to the level of the sea The sea-level plain is permanent in the absence of diastrophism. . . . Low lands with surfaces more inclined, and with more swiftly running streams, are still called *plains* though they are not fully brought down to baselevel; sometimes they are, called *peneplains* (1895, 34, 35).

Sea plain has not come into general use, perhaps because of possible confusion with sea-cut plains, or plains of marine denudation. The following extract gives an example of the

employment of the term with double meaning by Hughes, in describing the uplands of western Yorkshire:

> It is to both of the agencies above mentioned [marine and subaerial erosion], acting simultaneously throughout long ages, that we must refer the tremendous results that we have forced upon our attention We will refer to these great plateaux by the shorter term sea-plain; to distinguish them from the river-plains or bed-plains (131).

Dryer uses the phrase, "graded plain," in a somewhat different sense. The reduction of the border of a land area to a submarine plain by sea action, while the rest of the land surface is reduced to "baselevel" by subaerial processes, would result in the production of a "graded plain, lying partly above and partly below sea level" (234). No example of this kind of plain is mentioned. Gradation plain is used by Adams for a locally developed peneplain between residual ridges (508).

The terminology employed by Hayes departs somewhat from that in use with other writers. He says:

> The processes which tend to produce a baselevel plain are embraced under the term *gradation*. This includes aggradation and degradation. A *baseleveled surface* is any land surface, however small, which has been brought approximately to a baselevel, either general or local, by the processes of gradation. When such a surface has considerable extent it becomes a *baselevel plain*. The term *baselevel peneplain* or simply *peneplain* is applied to a surface of which a greater or less proportion has been reduced to the condition of a baselevel plain, but which contains also some unreduced residual areas (21, 22).

It seems to me that it is going too far to say that "a baselevel surface is any land surface, however small, which has been brought approximately to a baselevel, either general or local." It would follow from this definition that, inasmuch as every point in a continuously graded river is a local baselevel for every other point further up-stream, the upper stretches of the flood plain or broad valley floor of a large river would be called a baselevel surface, in spite of their standing several hundreds or even thousands of feet above the general baselevel. The valley plain of the Platte, for example, attains altitudes of more than 3,000 feet, and cannot be fitly described as a baselevel plain, unless baselevel is

taken to mean a sloping surface. It may be more appropriately called a graded valley plain, or a graded valley floor, for these terms do not contain any implication that the surface is either low or level.

Another objection to the above use of "baseleveled surface" is that it arbitrarily separates graded valley floors and graded hill sides, whose analogies with respect to the processes of gradation ought to be exhibited rather than concealed in a systematic terminology. It can hardly be supposed that anyone would today call a waste-covered hillside a "baseleveled surface," although it has every characteristic with respect to the processes of gradation that is possessed by a graded valley floor. A third objection to this use of "baseleveled surface" would be found when applying it to the High plains of eastern Colorado and western Kansas, which, according to the explanation offered by Johnson and cited above, were produced by aggradation during a time of less rainfall than at present. Here an extended surface was, as Hayes might phrase it, "brought approximately to a baselevel, either general or local, by the processes of gradation," and yet it was actually built up hundreds of feet above the pre-existent and the present valleys, and thousands of feet above the general baselevel, although there is no indication of any discontinuity in the graded surface between the High plains and the mouths of their aggrading rivers. The High plains are better called aggraded river-made plains, or *fluviatile plains;* and in this respect they resembled the great plains of northern India.

The geographical cycle.—The period of time during which an uplifted land mass undergoes its transformations by the processes of land sculpture, ending in a low featureless plain, has been called a geographical cycle, or, as Lawson phrases it, a "geomorphic cycle" (253). Hayes writes: "The term *gradation period* is employed for the entire time during which the baselevel remains in one position; that is, the interval between two elevations of the earth's surface of sufficient magnitude to produce a marked change in the position of sea level" (22),

but on later pages he uses the phrase "cycles of gradation" or simply "cycles" instead of "gradation periods." It matters little which of these terms is used; but it would certainly be an advantage that only one should be retained to express the single idea here considered.

Denudation and degradation.— It seems worth while to call attention in this connection to the desirability of a more careful discrimination than is customary between the terms, denudation and degradation. Denudation might be advisedly used as the name of those active processes, chiefly operative in the youth and maturity of a cycle, by which rock structures are laid bare, literally denuded, because their waste is removed as fast as it is formed. Degradation on the other hand is more appropriately associated with those liesurely processes, characteristic of the later stages of the cycle, in which a graded slope is reduced to fainter and fainter declivity, although maintaining its graded condition all the while. Aggradation is naturally the opposite of degradation, and implies the deposition of rock waste by transporting agencies, the built-up surface being always kept essentially at grade. Thus defined, denudation would accompany the early work of downward corrasion by streams, and the longer-lasting work of valley widening by weathering and washing. It would be systematically transmuted into degradation as the processes that operate on the various lines of down-slope streaming attained the graded condition; the large rivers first, the smaller branch streams later; the headwater streamlets and the hillside waste streams later still. Retreating cliffs and summit ledges, the last strongholds of denudation, would pass into the phase of degradation when they are reduced under the graded waste cover in the stage of subdued relief, characteristic of late maturity and early old age; and thenceforward all further erosion would be by degradation alone.

Conclusion.—It may seem at first reading that this essay is concerned with words rather than with facts; but such is not my intention. My object has been primarily to secure a just and accurate recognition of facts, and only secondarily to attach

words to the facts as convenient handles by which to bring the facts forward. It is a fact of large import that the wearing down of land masses proceeds in an orderly manner, involving the disclosure of bare rock ledges (denudation) in the earlier stages of the cycle of erosion, and the concealment of all ledges under a graded sheet of waste in the later stages of the cycle (degradation). It is a fact of much delicacy that streams tend to assume a balanced condition as to corrasion and transportation; that after once attaining this condition they preserve it as long as their work continues without disturbance; but that the slope of their graded courses must vary systematically through the stages of maturity and old age, as well as through changes of climate. It is a fact of great value in geographical description that the balanced condition of water streams is imitated so closely by that of waste streams that one set of terms applies to both kinds of streams.

There can be no question that the adoption of a suitable term as the name for a fact is a great aid to the general recognition of the fact itself. It is largely on this account, as well as in the interests of a precise terminology, that I have here written out a series of notes that have been gathered during the past two years, and of which some account was given at the meeting of the Geological Society of America in Washington, in December, 1899.

It is admittedly difficult always to use terms in a manner that is perfectly consistent with their definitions. It is rarely possible to limit terms to a single meaning. It is probable that in this attempt to reduce our terminology to greater simplicity and better order than now prevails I have laid myself open to criticism on the very grounds that are objected to in the course of this essay. Further discussion may therefore be advisedly directed to a settlement of open questions. It is certainly open to consideration whether "denudation" and "degradation" should be limited as above suggested; but the advisability of holding "baselevel" and "grade" to the meanings here indicated seems to me much less open to difference of opinion. The future

meanings of these words will depend much less on the preference of the older geologists and geographers of today than on that of their younger successors. I therefore urge those who are now taking up the use of such terms as baselevel and grade, denudation and degradation, to consider carefully the meaning to be adopted for them.

W. M. DAVIS.

LIST OF AUTHORS CITED.

G. I. Adams, "Physiography of the Arkansas Valley Region" (abstract), *Science*, XI, 1900, 508.

A. P. Brigham, *A Text-Book of Geology*. New York: Appleton, 1901.

M. C. Campbell, "Drainage Modification and their Interpretation," JOUR. GEOL., IV, 1896, 567–587, 657–678.

H. C. Cowles, "Physiographic Ecology of Chicago and Vicinity," *Botan. Gazette*, XXXI, 1901, 73–108, 145–182.

N. H. Darton, "Outline of Cenozoic History of a Portion of the Middle Atlantic Slope," JOUR. GEOL., II, 1894, 568–587.

M. F. B. Dausse, "Note sur un Principe important et nouveau d'Hydraulique." *C. R. Acad. Sciences, Paris*, XLIV, 1857, 756–766.

W. M. Davis, "Geographic Methods in Geologic Investigation," *Nat. Geogr. Mag.*, I, 1889, 11–26.

—— "Physical Geography in the University," JOUR. GEOL., II, 1894, 66–100.

—— "A Speculation in Topographical Climatology," *Amer. Meteorol. Jour.*, XII, 1896, 372–381.

—— "An Excursion to the Grand Canyon of the Colorado," *Bull. Museum. Comp. Zoöl. Harvard College*, XXXIII, 1901, 107–201.

W. M. Davis and J. W. Wood, Jr., "The Geographic Development of Northern New Jersey," *Proc. Boston Soc. Nat. Hist.*, XXIV, 1889, 365–423.

J. S. Diller, "Tertiary Revolution in the Topography of the Pacific Coast," *Fourteenth Ann. Rep. U. S. Geol. Survey*, 1894, Pt. II, 397–434.

C. R. Dryer, *Lessons in Physical Geography*. New York: American Book Co., 1901.

C. E. Dutton, "Tertiary History of the Grand Canyon District," *Monogr. II, U. S. Geol. Survey*, 1882.

H. W. Fairbanks, "Notes on the Geology of Eastern California," *Amer. Geol.*, XVII, 1896, 63–74.

H. Gannett, "Physiographic Types," *U. S. Geol. Surv., Topogr. Atlas U. S.*, Folio 1, 1896; Folio 2, 1900.

J. Geikie, *Earth Sculpture or the Origin of Land-Forms*. London: Murray, 1898.

G. K. Gilbert, "The Colorado Plateaux Province as a Field for Geological Study," *Amer. Jour. Sci.*, XII, 1876, 16–24, 85–103.

—— "Report on the Geology of the Henry Mountains," *Dept. of Interior, U. S. Geogr. and Geol. Survey, Rocky Mountain Region*, 1877.

—— "The Underground Water of the Arkansas Valley in Eastern Colorado," *Seventeenth Ann. Rep. U. S. Geol. Survey*, Pt. II, 1896, 551–601.

G. Greenwood, *Rain and Rivers.* London: Longmans, 1857.

C. W. Hayes, "Physiography of the Chattanooga District in Tennessee, Georgia, and Alabama," *Nineteenth Ann. Rep. U. S. Geol. Survey*, 1899, Pt. II, 1–58.

R. T. Hill, "The Geological History of the Isthmus of Panama and Portions of Costa Rica," *Bull. Museum Comp. Zoöl., Harvard College*, XXVIII, 1898, 151–285.

W. H. Hobbs, "The Newark System of Pomperaug Valley, Connecticut," *Twenty-first Ann. Rep. U. S. Geol. Survey*, Pt. III, 1901, 7–162.

T. McK. Hughes, "Ingleborough, Pt. I, Physical Geography," *Proc. Yorkshire Geol. and Polytech. Soc.*, XIV, 1901, 125–150.

W. D. Johnson, "The High Plains and their Utilization," *Twenty-first Ann. Rep. U. S. Geol. Survey*, 1901, Pt. IV, 601–741.

A. Keith, "Geology of the Catoctin Belt," *Fourteenth Ann. Rep. U. S. Geol. Survey*, Pt. II, 1894, 285–395.

H. B. Kümmel, "Some Rivers of Connecticut," JOUR. GEOL., I, 1893, 371–393.

A. C. Lawson, "The Geomorphogeny of the Coast of Northern California," *Bull. Dept. Geol. Univ. Cala.*, I, 1894, 241–271.

W J McGee, "The Geology of the Head of Chesapeake Bay," *Seventh Ann. Rep. U. S. Geol. Survey*, 1888, 537–646.

—— "The Pleistocene History of Northeastern Iowa," *Eleventh Ann. Rep. U. S. Geol. Survey*, 1891, 189–577.

J. E. Marr, *The Scientific Study of Scenery.* London: Methuen, 1900.

H. R. Mill, *The International Geography.* London: Newnes, 1899.

R. D. Oldham, "On the law that governs the action of flowing streams." *Quart. Jour. Geol. Soc.*, XLIV, 1888, 733–738.

A. Phillipson, "Ein Beitrag zur Erosionstheorie." *Petermann's Mitt.*, XXXII, 1866, 67–79.

J. W. Powell, *Exploration of the Colorado River of the West and Its Tributaries.* Washington, 1875.

—— "Physiographic Processes": "Physiographic Features," *Nat. Geogr. Monogr.*, 1895, 1–32, 33–64. New York: American Book Co.

W. N. Rice, editor of *Revised Text-Book of Geology*, by James D. Dana. New York: American Book Co., 1897.

I. C. Russell, *Rivers of North America.* New York: Putnam, 1898.

R. D. Salisbury, "Surface Geology," *Geol. Survey N. J., Ann. Rep. State Geol. for 1892–3*, 35–246.

—— "The Physical Geography of New Jersey," *Geol. Survey N. J. Final. Report*, IV, 1898.

W. B. Scott, *An Introduction to Geology*. New York: Macmillan, 1897.

R. S. Tarr, *Elementary Physical Geography*. New York; Macmillan, 1895.

C. R. Van Hise, "A Central Wisconsin Baselevel," *Science*, IV, 1896, 57–59.

B. Willis, "The Northern Appalachians," *Nat. Geogr. Monogr.*, 1895, 169–202. New York: American Book Co.

—— "Paleozoic appalachia," *Maryland Geol. Survey*, IV, 1900, 23–93.

A. Winslow, "Lead and Zinc Deposits," *Missouri Geol. Survey*, VI, 1894.